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LPD17 Amphibious Dock Ship: Fire Hazard Assessment of the Forward and Aft AEM/S System Masts

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The risk of a fire incident for the LPD17 masts has been considerably reduced in comparison to that of the ATD AEM/S Systems, which was previously characterized as very low. The fire hazard (characterization of the likely impact of a fire event) for the LPD17 masts is similar to that of the ATD mast, which was determined to be low. The life safety of occupants has been improved with the omission of portable ladders as well as the redesign of the joint system between the antenna foundations and the side walls of the masts. The improvements in active/automatic suppression capabilities integrated with the design of the LPD17 masts are pivotal in managing the fire hazard associated with either internal or external fire scenarios. The effectiveness of the internal deluge water spray systems is notably increased when coupled with the early detection capabilities of an air sampling smoke detection system. Overall, the design of the LPD17 AEM/S Systems adequately manages the fire risk and hazard associated with the combustible composite materials. The fire protection features which can be used to address the threat include fire prevention, life safety and egress, detection, suppression and passive features. Each of these aspects has been expanded below. Based on this list of either current design features or recommended fire protection features, appropriate firefighting doctrine and tactics using a quick response philosophy can be implemented.

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NOMENCLATURE

ATD	Advanced Technology Demonstration
AEM/S	Advanced, Enclosed Mast/Sensor System
RCS	radar cross section
NSWC/CD	Naval Surface Warfare Center/Carderock Division
NAVSEASYSCOM	Naval Sea Systems Command
ITD	Integrated Topside Design
PFP	Passive Fire Protection
FSS	Frequency Selective Surface
GRP	glass reinforced plastic
SCRIMP	Seemann Composite Resin Infusion Molding Process
PVC	polyvinylchloride
SPS-48E	air search radar
SPQ-9B	surface search radar
HF	high frequency
UHF	ultra-high frequency
VHF	very high frequency
FM	frequency modulation
TV	television
CPS	collective protection system
HS	high strength
EMI	electromagnetic interference
ICA	integrated communications antenna
CMWD	counter measure washdown
CO_2	carbon dioxide
EEBD	emergency escape breathing device
HYDRA	radio frequency, wireless communications system
SOP	standard operating procedure
TAS	target acquisition system
SEED	Supplementary Emergency Escape Device
RFI	radio frequency interference
VESDA	very early smoke detection activation
MCT	multiple cable transits
NSTM	Naval Standard Technical Manual
NWP	Naval Warfare Publication
DCA	Damage Control Assistant
OOD	Officer of the Deck

LPD17 Amphibious Dock Ship: Fire Hazard Assessment of the Forward and Aft AEM/S System Masts

1.0 INTRODUCTION

A successful Advanced Technology Demonstration (ATD) which focused on the installation and sea trials of the Advanced, Enclosed Mast/Sensor System (AEM/S) on the USS RADFORD (DD968) has prompted the pursuit to modify the LPD17 Class design to include similar technology. Design change requests (AIRs and FMRs) which replace both the forward and aft stick masts with AEM/S System masts have been approved. As with the ATD mast, the AEM/S Systems masts proposed for the LPD17 platform represent enhanced war fighting capabilities by integrating sensor, signature reduction, electromagnetics, advanced materials structures and manufacturing technologies.

The forward and aft composite masts designed for the LPD17 utilize 10 degree sloped surfaces (from the vertical axis) and an octagonal cross section. This design minimizes the radar cross section (RCS) of the masts, as four sides of each mast structure are aligned with the primary ship structure. The more obtuse angles created by adjacent sides, in comparison with the six-sided ATD mast, maximize the radar performance. The design of the LPD17 masts facilitates sensor suite upgrades allowing 360 degree coverage for future phased sensor arrays.

The forward and aft LPD17 mast designs will use composite assemblies similar to the ATD mast. As such, a notable quantity of combustible material is being introduced to the ship design. The use of combustible materials for shipboard applications has been historically discouraged, limited or prohibited. A number of issues arise as a result of the composite forward and aft masts under design for the LPD17. The Survivability Structures and Materials Directorate of the Naval Surface Warfare Center, Carderock Division (NSWC/CD) and Bath Iron Works

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have worked closely with Naval Sea Systems Command (NAVSEASYSCOM), Code 05L4, to ensure that fire protection and safety related issues are resolved. Based on the lessons learned from the ATD AEM/S program, NSCWC/CD and NAVSEASYSCOM have implemented program requirements, which address many of the concerns. The advances in the LPD17 mast designs have leveraged the knowledge gained from the previous fire hazard analysis of the ATD AEM/S System.

This fire hazard analysis drew heavily from the fire hazard evaluation performed on the AEM/S System ATD[1]. Other efforts relating to composite materials influenced the direction of technical issues; for example, the DD21 Integrated Topside Design (ITD) program has aggressively researched broad spectrum issues associated with composite applications [2]. Fire safety-related decisions were made early on in the design process for the LPD17 masts which reflected the state-of-the-art technical understanding of composite structures and their application to surface ship installations.

2.0 BACKGROUND

The fire hazard analysis performed for the AEM/S System ATD mast [1] was used as the basis for the current hazard assessment. The focus of the previous assessment was to determine probable fire threats, estimate fire effects on the mast environment and identify fire prevention and mitigation strategies. Plausible ancillary fuel sources as well as ignition sources within the mast were identified. Failure criteria were established in order to define the hazardous conditions in the context of the AEM/S Systems mast. Flame spread computer modeling, based on the Passive Fire Protection (PFP) Large-Scale Testing and Modeling efforts [3, 4], was performed to assess the potential for extensive, rapid flame spread over large portions of the composite assemblies. Additionally, computer fire modeling was performed to determine if there is a potential threat to the structure or sensor equipment and if there are tenability concerns for either protected or unprotected personnel.

The flame spread modeling indicated that self-propagating flame spread was unlikely to occur and that portions of the composite assembly proportional to the exposure fire would become involved but eventually self-extinguish. The general fire modeling results demonstrated that large enough fires could develop to threaten an electronic sensor and the TAS deck mounting; however, there were no plausible initiating fires of sufficient magnitude to generate these conditions. Relatively small fires were also found to potentially create untenable conditions for an unprotected crew. Overall, the fire hazard was found to be low for the AEM/S ATD mast and the fire risk very low. Recommendations were made regarding fire prevention strategies, egress, and life safety, fire detection, fire suppression strategies, passive fire protection and damage control and fire fighting tactics.

Anecdotal feedback from the RADFORD has been generally encouraging. Significant improvement in radar performance has been realized with the AEM/S System. Corrosion maintenance has also been reduced. The crew likes the climber safety devices and there is a comfort level associated with going up the AEM/S System while underway. The stored portable ladders are acceptable but there are difficulties in erecting the ladders while underway. This emphasizes the improvement represented by the inclusion of foldable, telescoping and fixed ladder arrangements proposed for the LPD17 AEM/S Systems.

3.0 DESCRIPTION OF THE LPD17 MASTS

The AEM/S System concept as applied to the LPD17 forward and aft mast concept consists of enclosing the primary radars and antennas inside of an octagonal, pyramidal-type structure. The external composite structure serves dual purposes: it is the primary mast structure as well as the radome for the enclosed antennas and radars. The design consists of a fiberglass-vinyl-ester resin laminate skins, sandwiched over a foam core. Embedded inside the core are one or more film layers printed with copper patterns. The spacing and specific patterns of the layers, in conjunction with the structural skins, results in a frequency selective surface (FSS) which is tailored specifically to the operational characteristics of the enclosed radar systems.

3.1 Structural Description

The aft mast is a 20.8 m (68.2 ft) tall octagonal structure of varying diameter. Figures 1 and 2 present a section and plan view of the aft mast respectively. Measuring from flat to flat, the diameter of the structure is 13 m (42.7 ft) at its base (04 level). The mast tapers linearly to 5.9 m (19.5 ft) at the Crow's Nest Platform level, 17.2 m (56.4 ft) above the 04 level. There is an intermediate level for the SPS-58E radar at approximately 5.6 m (18.4 ft) above the 04 level.

The forward mast is a 10.1 m (33 ft) tall octagonal structure of varying diameter. Figures 3 and 4 show a section and plan view of the forward mast respectively. Measuring from flat to flat, the diameter of the structure is 9.5 m (31.2 ft) at the base of the mast. The mast tapers linearly to 5.3 m (17.4 ft) at the Crow's Nest Platform level at 8.4 m (27.6 ft) above the base of the mast. There are two intermediate levels within the forward mast created by a platform located at approximately 4.7 m (15.4 ft) above the base of the mast. The top of the forward AEM/S System includes a random pedestal/foundation for the SPQ-9B radar unit.

3.2 Mast Access and Communicable Openings

Access to the mast and access between the various levels of each mast is important to both manual firefighting and egress issues. The forward and aft AEM/S Systems are described in detail below.

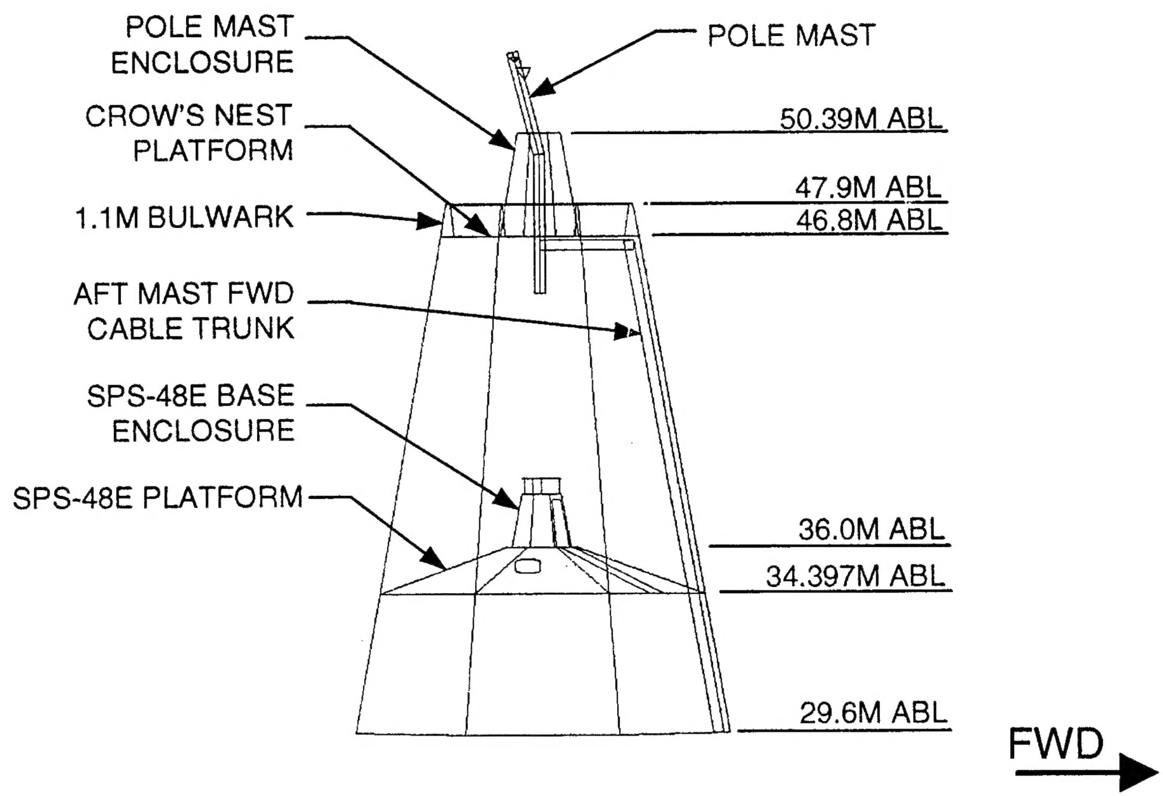

Fig. 1 – Section view of aft AEM/S system

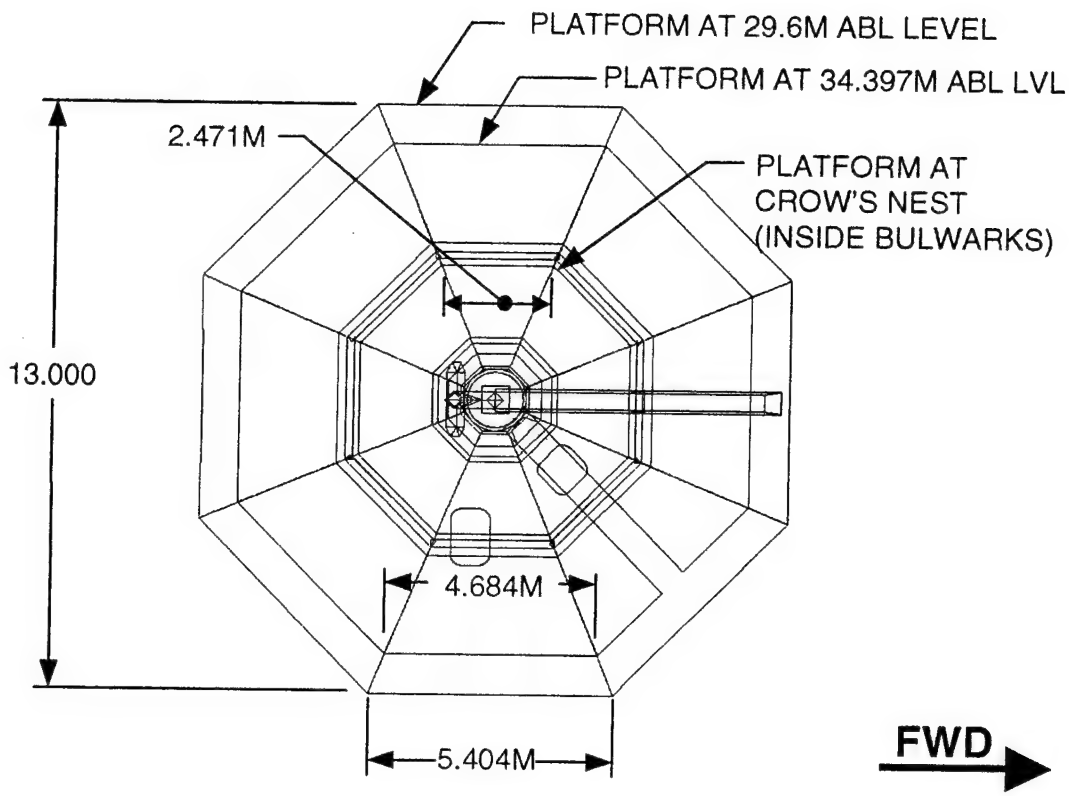

Fig. 2 – Plan view of aft AEM/S system

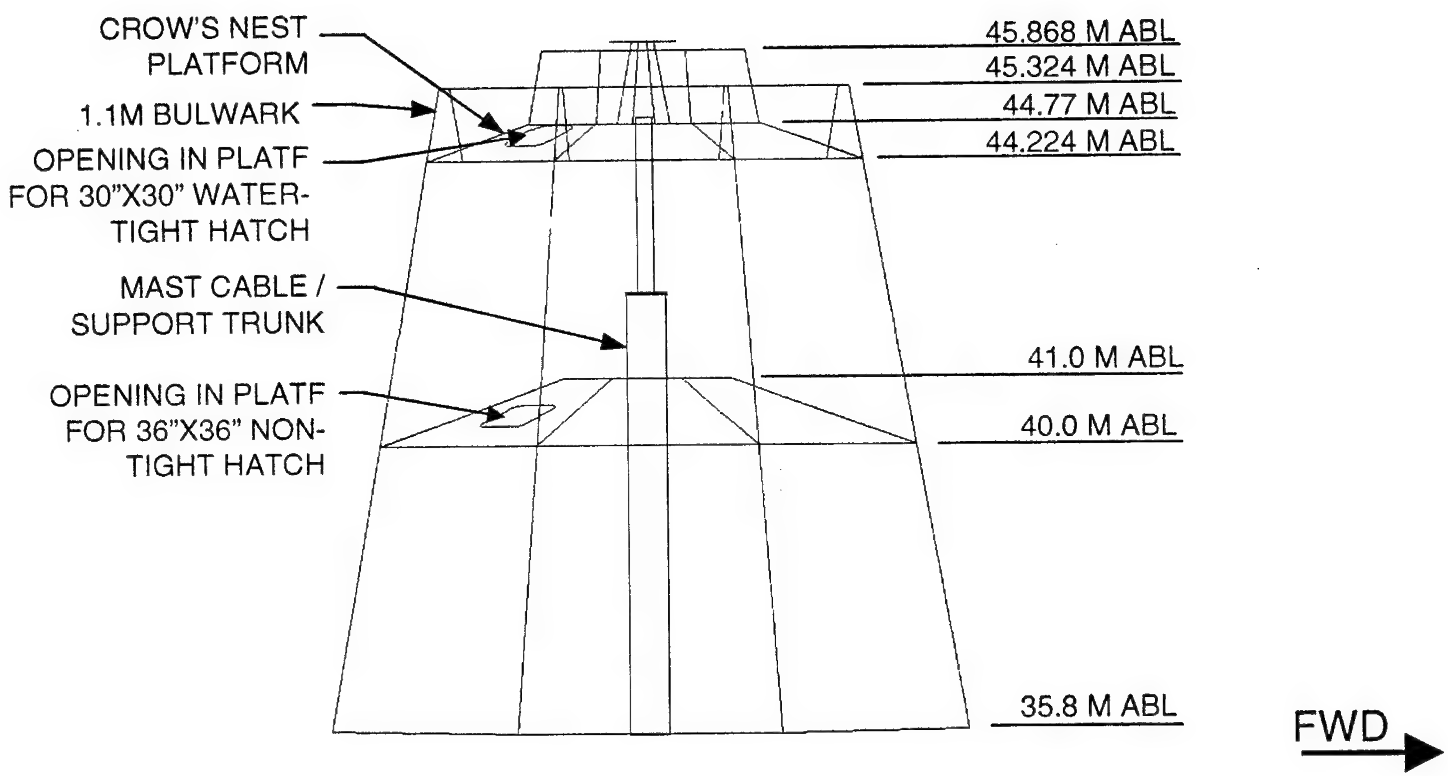

Fig. 3 – Section view of forward AEM/S system

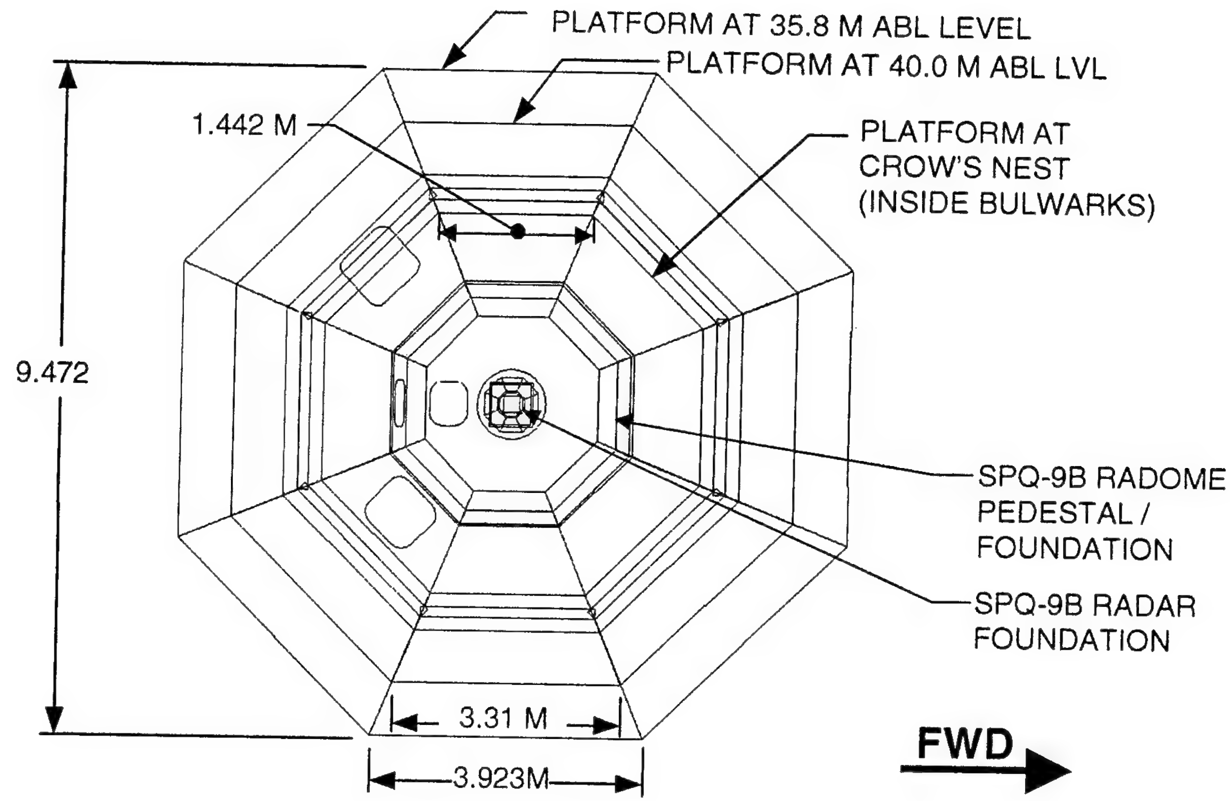

Fig. 4 – Plan view of forward AEM/S system

3.2.1 AFT Mast

Access to the aft mast is from the pressure lock at frame 112 of the 03 level. The pressure lock consists of an inclined ladder with a hatch in the overhead at the top of the ladder. Entrance to the pressure lock can be gained from either the weather at frame 115 or from Radar Room No. 2. This is depicted in Figure 5. The pressure lock leads to the access space of the aft mast that is constructed from a non-FSS balsa core sandwich composite. Above the access space is the SPS-48E space. Two fixed ladders with an intermediate platform span the 5.6 m (18.4 ft) height necessary to enter the SPS-48E space through a 76.2 cm x 121.9 cm (30 in. x 48 in.) non-tight, light weight aluminum hatch. The SPS-48E space is extremely tall with a height of 11.6 m (38.1 ft). The overhead of the SPS-48E space forms the Crow's Nest Platform and the base of the pole mast enclosure. In order to access the crow's nest from the SPS-48E space, a 11.9 m (39.0 ft) telescoping extension ladder, equipped with climber safety gear, must be used. This three-section ladder is stored in a recess of the SPS-48E platform. Once the rotational antenna is stopped, the ladder can be extended to the 91.4 cm x 91.4 cm (36 in x 36 in) watertight hatch in the overhead. The access arrangement for the aft mast is depicted in Figures 6 and 7.

3.2.2 Forward Mast

Access to the forward AEM/S Systems is also from a pressure lock, located at frame 49 of the 05 level. Entrance to the pressure lock is via a companionway or from the Mast Equipment Room. Access to the Mast Equipment Room is governed by the hatch at frame 44. The access arrangement from the 05 level is shown in Figure 8. Pressure lock access from the 05 level allows entry into the lower of the two intermediate mast spaces, both of which utilize FSS assemblies. Access from the lower intermediate space to the upper intermediate space is by a 2 piece folding ladder, which is stored in the place of erection. This ladder serves a 91.4 cm x 91.4 cm (36 in x 36 in) non-tight hatch by spanning the 4.7 m (15.4 ft) vertical height of the lower intermediate space. Once in the upper intermediate space, access to the crow's nest

03 LEVEL AFT AEM/S VENTILATION PROPOSAL

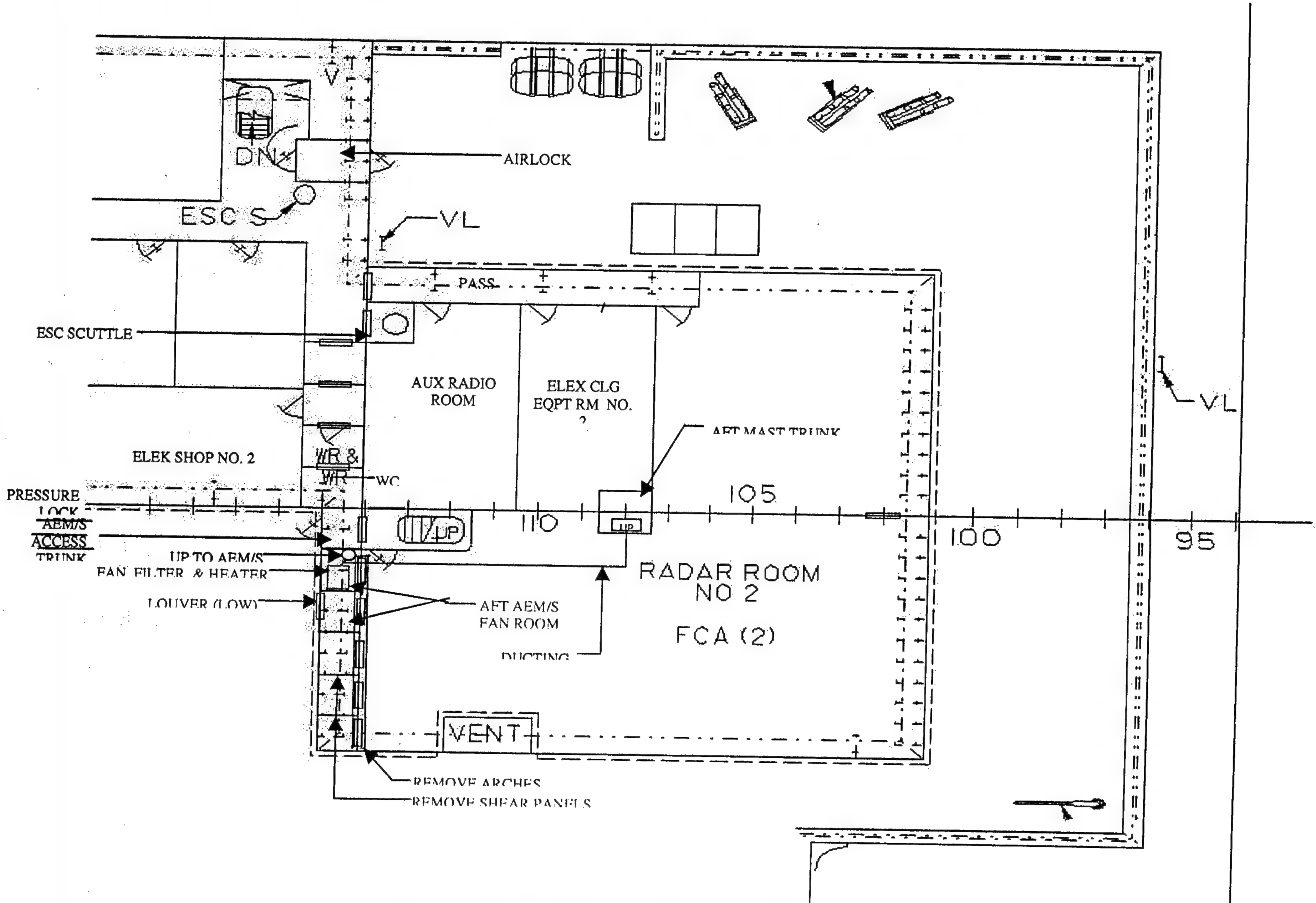

Fig. 5 – Access and ventilation arrangement for aft AEM/S system

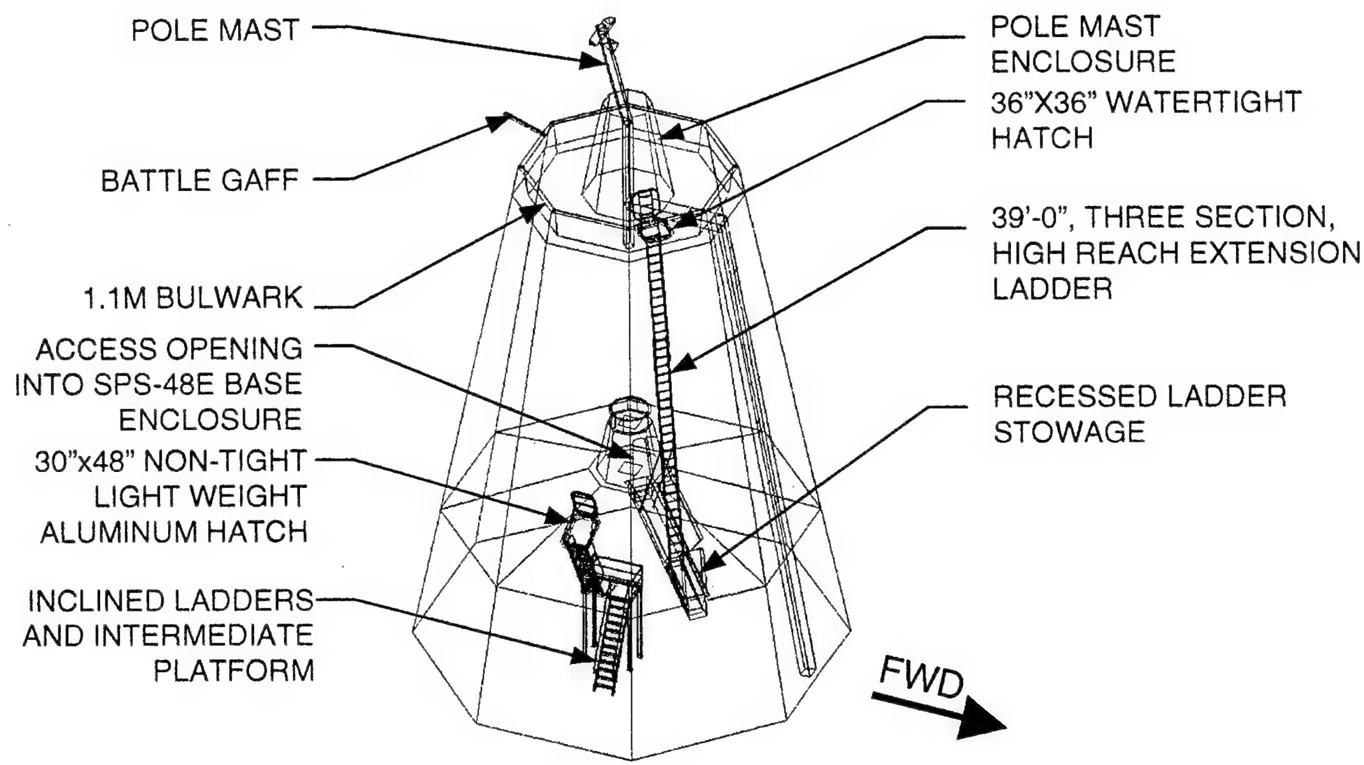

Fig. 6 – Isometric view of aft AEM/S access

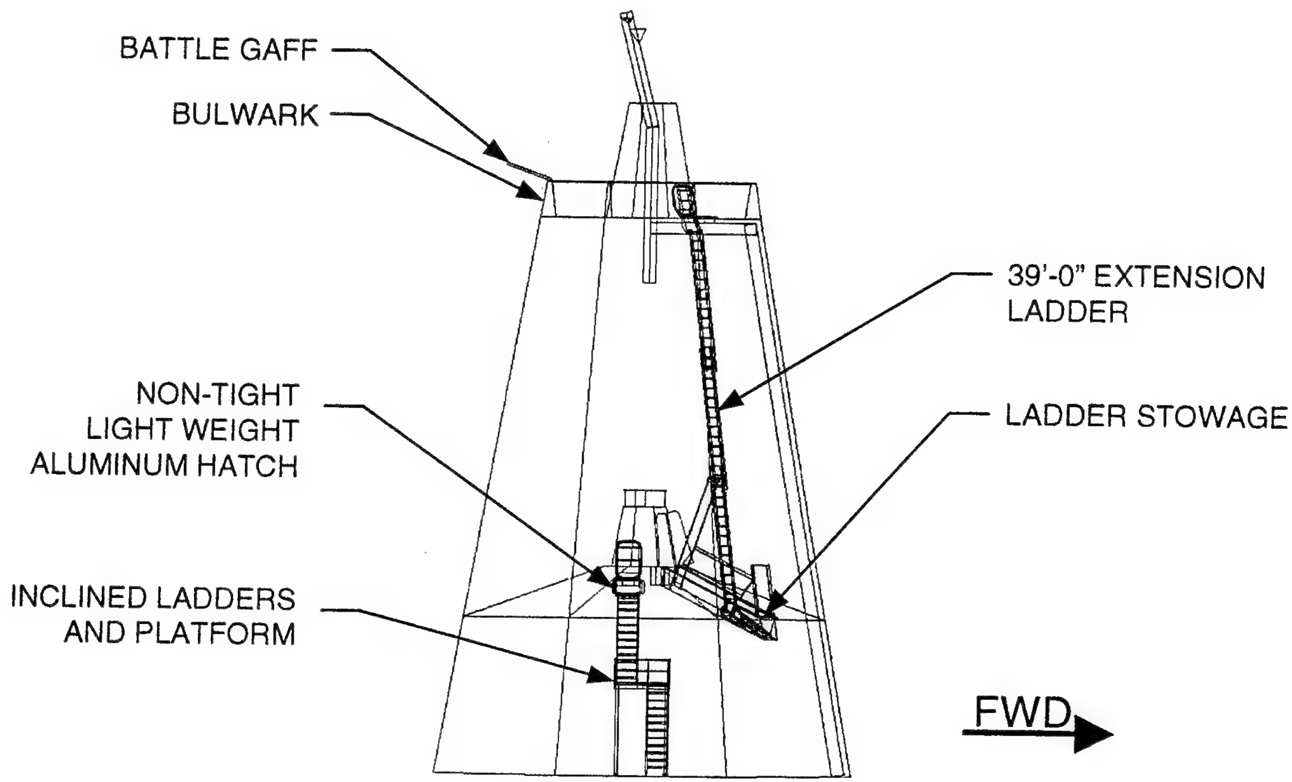

Fig. 7 – Section view of aft AEM/S access

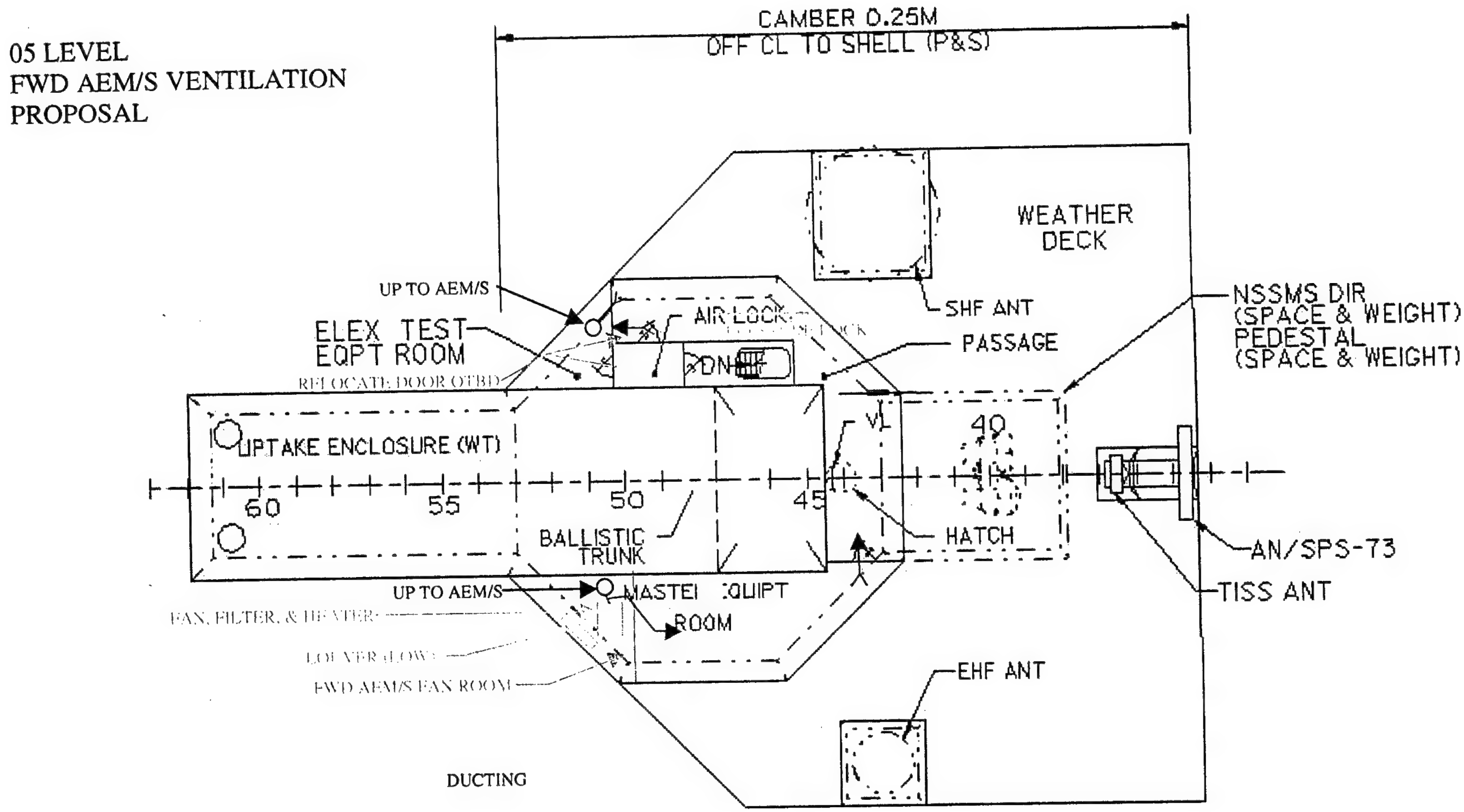

Fig. 8 – Access and ventilation arrangement for forward AEM/S system

as well as the SPQ-9B random pedestal/foundation is via a three piece folding ladder. Again, the ladder is stored at the place of erection. This ladder serves a 76.2 cm x 76.2 cm (30 in x 30 in) flush, watertight hatch in the overhead/crow's nest platform. This three piece folding ladder spans the 4.0 m (13.1 ft) vertical height to the crow's nest. Both folding ladders will incorporate climber safety equipment. Figures 9 and 10 illustrate the ladder access design for the forward mast.

3.3 Antenna Configuration

The structural design of the AEM/S System is based on a modular concept. The modular approach enables the AEM/S System to be upgraded as more advanced sensor and combat system suites become available. The ability to retrofit or upgrade radar system suite allows for the most current sensor technology to be incorporated into the respective LPD17 flight under construction/design. This change-out capability requires attention early in the design process relative to the selection and location of enclosed sensor systems. Other critical design aspects associated with the change-out ability are joint concepts, platform design and fabrication approaches.

3.4 Detachable Joints

The AEM/S masts are vertically segmented to create multiple radome sections. The modular concept of the AEM/S Systems for the LPD17 requires detachable joints between adjacent radome sections. This allows for the ability to gain access for sensor system upgrades. Where possible, a single detachable joint design is being used for similar joint locations between the forward and aft masts. This simplifies design, fabrication and testing. The principal parameters for the design of detachable joints include: the structural integrity under design loads, the minimum electromagnetic obstructions of the enclosed radar systems, the impact on mast RCS, the incorporation of platform support into the side-shell joint and the ease of fabrication and change-out.

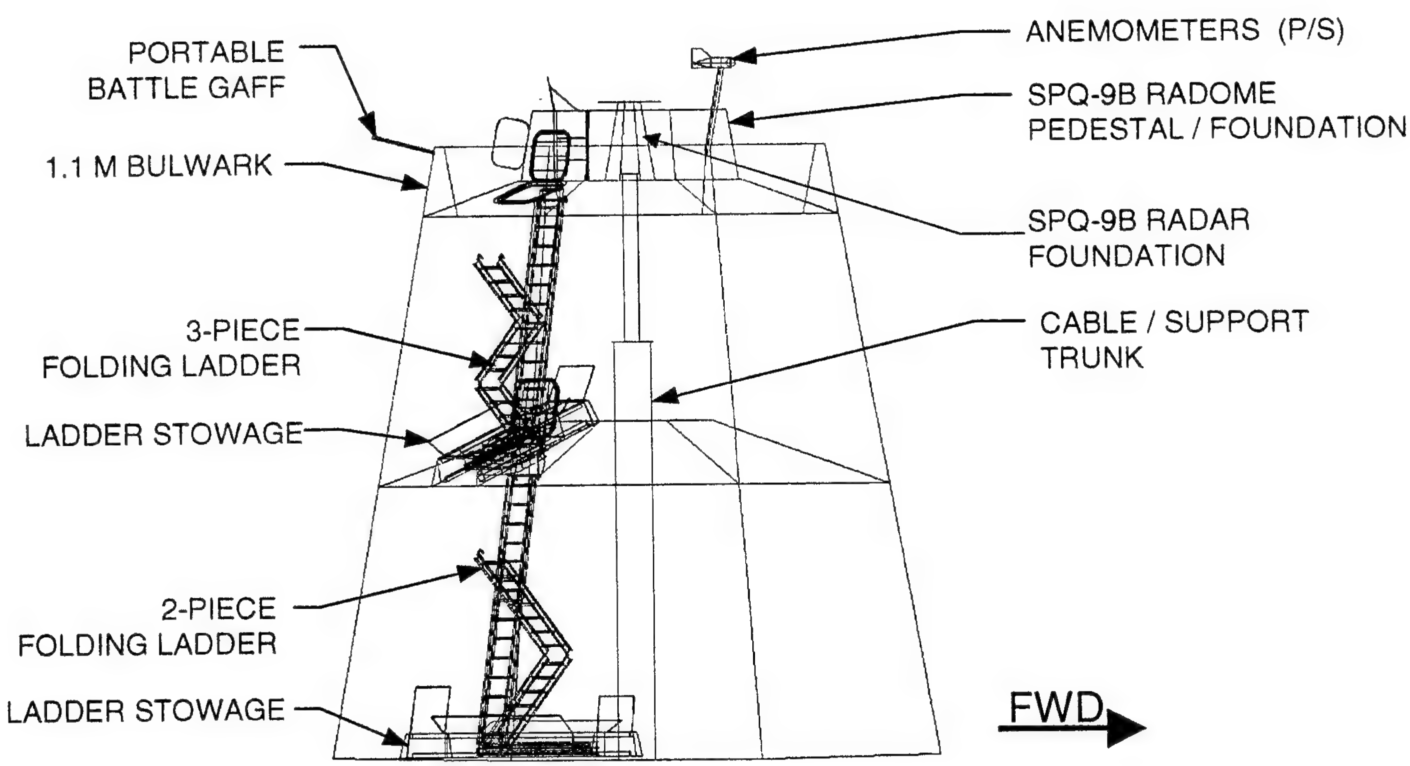

Fig. 9 – Section view of forward AEM/S access

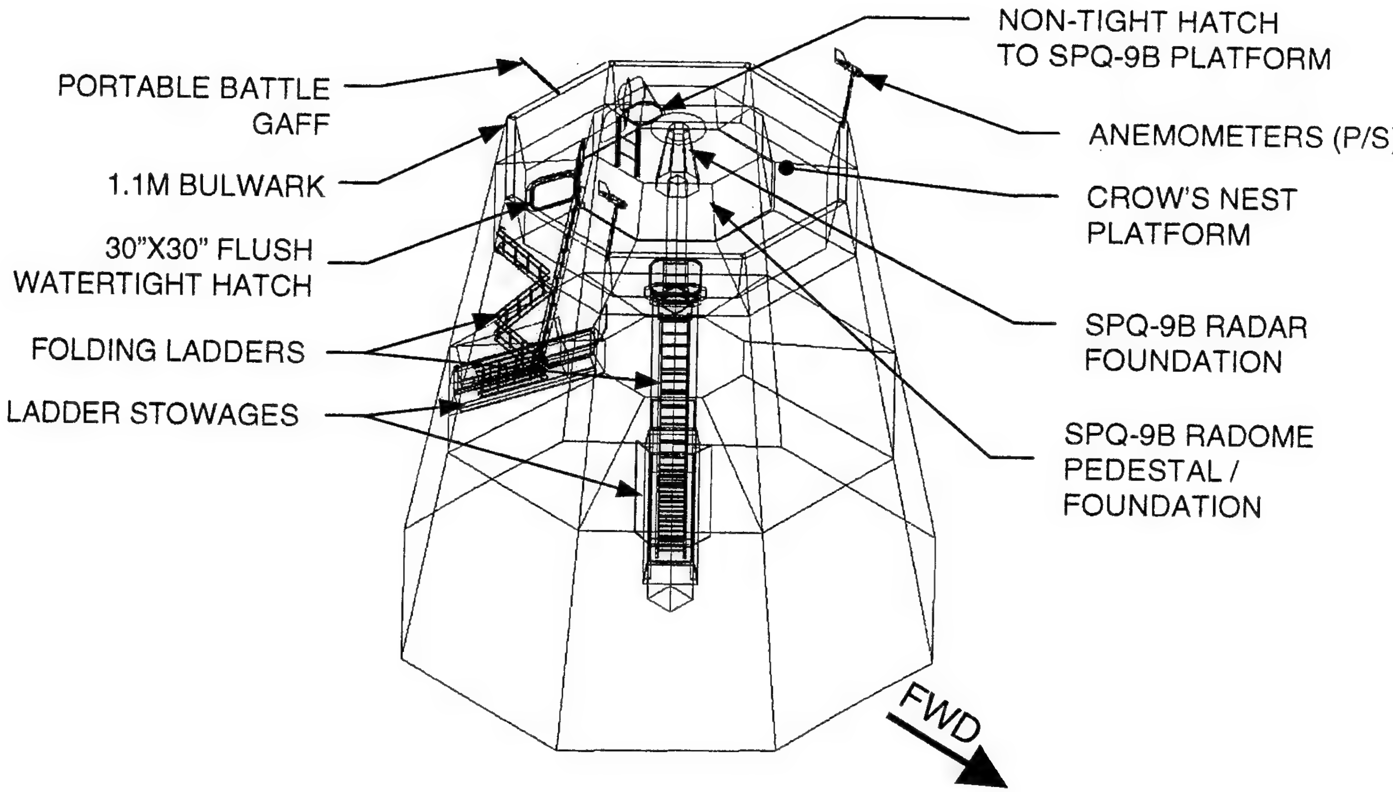

Fig. 10 – Isometric view of forward AEM/S access

The current joint design employs composite double lap-joints with stainless steel bolts in order to mate adjacent sections of the mast. The composite sandwich configuration remains continuous through the joint, which minimizes antenna blockage compared with composite shell panels that taper to a solid laminate. This is accomplished by using a higher density structural foam (40# LAST-A-FOAM) in place of the FSS foam material. This allows adequate bolt torque without crushing the core material. Additionally, the outer composite skins have increased thickness in the joint area to provide sufficient bolt bearing area and additional strength. Figure 11 illustrates the detachable joint concept.

3.5 Base Joint

The proposed mating connection between the lower composite portion of the enclosed mast and the steel ship structure will use either one or two steel flanges bolted to the mast side shell. A single flange has been assumed for preliminary design purposes. The side shell will taper from a sandwich assembly to solid laminate construction in the area of the joint. In addition to tapering to a solid laminate, the shell skin will be locally thickened to carry the associated bolt loads. The side shell construction of two 0.38 cm thick Glass Reinforced Plastic (GRP) skins will transition to a solid, 1.27 cm thick solid laminate. Figure 12 shows the preliminary base joint concept.

3.6 Antenna Platforms

Platforms are installed within the forward and aft mast structures to support antenna sensors. Each antenna and associated equipment will be mounted to a dedicated metallic foundation in the center of a platform, both having an octagon shape. The foundation is bolted to a cambered composite platform, which is comprised of eight faceted panels. The composite platform utilizes sandwich construction of fiberglass reinforced vinylester skins encapsulating a balsa wood core. The platform panels taper to a solid laminate at both the inner and outer

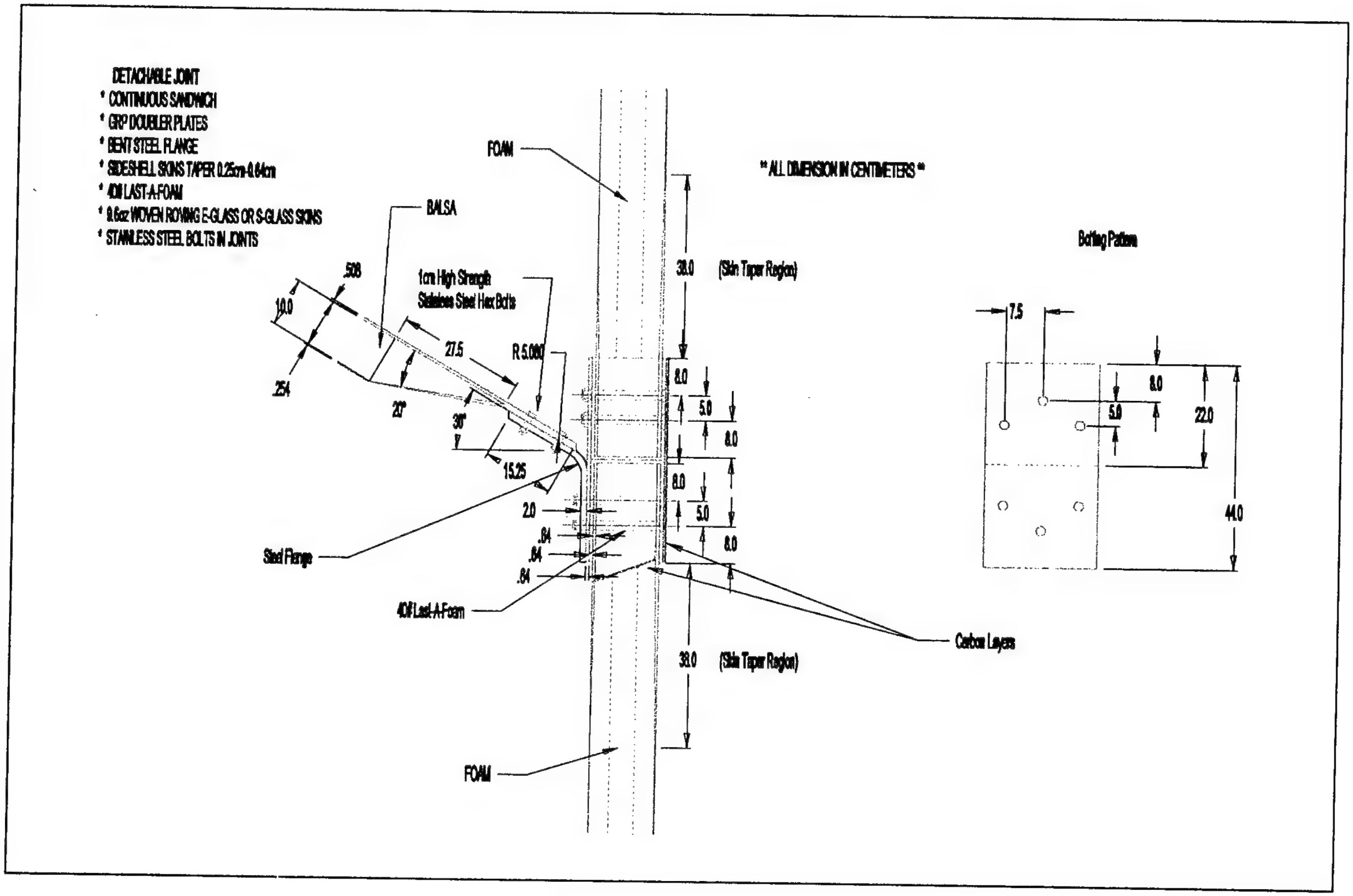

Fig. 11 – Detachable joint concept

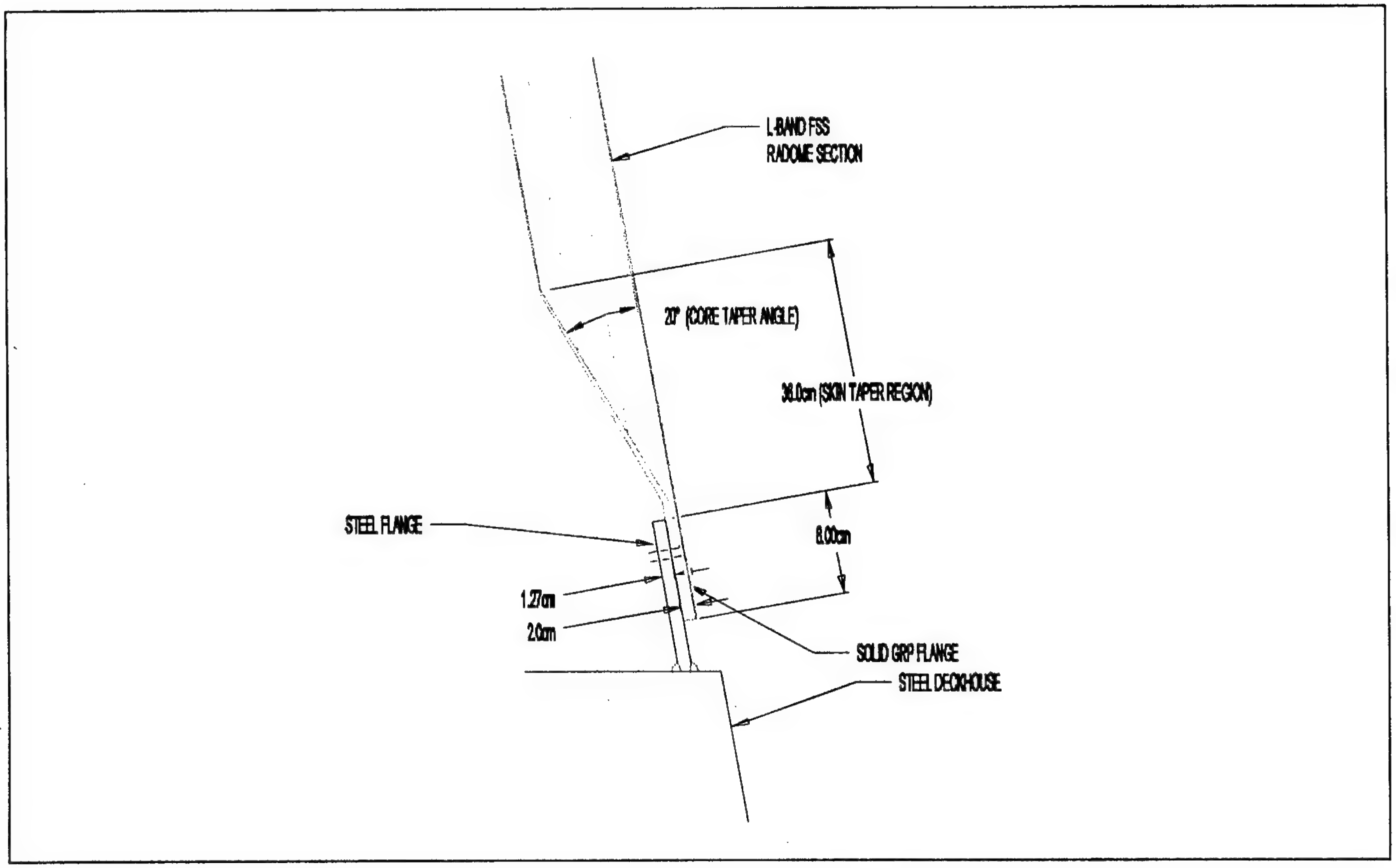

Fig. 12 – Preliminary base joint concept

extremities where it will be connected to the foundation and to the side shell bolting flange respectively. For the purposes of this analysis, the bolting flange, which connects the platform to the side shell of the mast, is assumed to be GRP. The alternative is steel; however, the GRP bolting flange represents a weight savings over the steel flange. The platform construction and joint configuration are depicted in Figure 13.

3.7 Composite Material Data

The preliminary design of the LPD17 AEM/S Systems has been based on a material system consisting of either E-Glass or S-Glass fibers in a Dow Derakane 510-A-40 vinylester resin matrix. The laminated assemblies will be fabricated utilizing the Seemann Composites Resin Infusion Molding Process (SCRIMP). There have been four core materials identified for use in various areas of the overall mast structure. The FSS assemblies will be constructed with Diab Divinylcell HT-90 for the external layer and H-80 for the other layers. The inserts of higher density structural foam will be LAST-A-FOAM FR6740. The core material for the platform panels will be BALTEK End-grain Balsa D100 (9.5lb/ft^3), with the standard AL/600 coating and hot-coating.

3.8 Composite Assemblies Descriptions

The forward and aft AEM/S Systems employ a sandwich composite assembly design. The FSS assemblies include: L-band for the aft AEM/S pole mast enclosure; S-band for the aft AEM/S SPS-48E radome and L-band for the forward AEM/S intermediate radome sections. These assemblies use a 14 cm (5.5 in) thick PVC (Diab Diviny/Cell) core with 0.25 cm (0.1 in) thick outer vinylester skins. The FSS assemblies for these radome sections also include the appropriate frequency selective screens internal to this assembly. The access space of the aft mast (below the SPS-48E radome section) does not utilize a FSS. Rather, a sandwich assembly with a 14 cm (5.5 in) thick balsa wood core and 0.25 cm (0.1 in) thick outer vinylester skin is utilized.

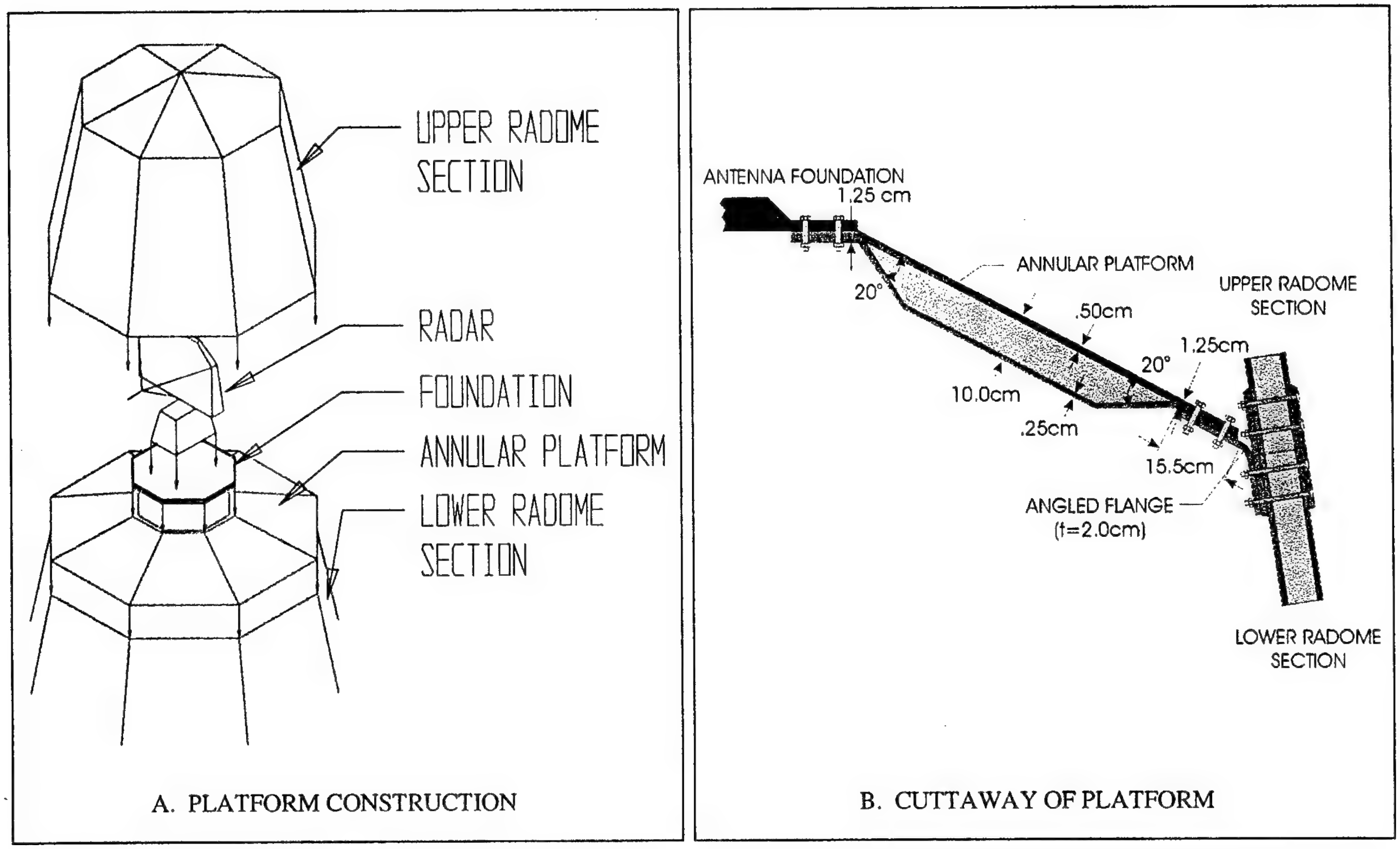

Fig. 13 – Antenna platform construction and joint configuration

3.9 Equipment within the Mast

3.9.1 Radar Antenna

There are numerous radar, sensors and antennas located on the forward and aft AEM/S systems for the LPD17. The two largest, rotational radar units are the air search radar (SPS-48E) located in the aft mast and the surface search radar (SPQ-9B) located on the top of the forward mast. Due to the nature of their operation, these antennae are positioned and controlled by electric motors. The SPS-48E radome section of the aft mast also houses several sensors/ antennas in addition to the SPS-48E air search radar: VHF-HOP, UHF HOP SCVR, UHF HVDRA, AN/KSQ-1 (EPLRS), IFF Test Set and IFF Interrogator. The access space of the aft mast (non-FSS) houses a modified HF antenna. The pole mast enclosure (L-band FSS) of the aft mast houses two UHF LOS XCVR antennas as well as a CETPS antenna. The pole mast primarily supports the JTIDS and TACIAN antennas. The forward AEM/S System provides the radome pedestal/foundation for the SPQ-9B surface search radar and does not house/enclose this unit. The two intermediate radome sections (L-band FSS) of the forward mast enclose several senors/antennas. The lower radome section houses the following sensors: VLF/LF/MF/HF; VHF HOP; VHF FM XGVR; UHF QMS RCV; UHF Data Link XCVR; AN/K SQ-1 (EPLRS) and an AN/UPX-28(v). The upper radome area contains the following sensors/antennas: VHF HOP; VHF AM XCVR; UHF LOS XCVR; UHF HYDRA; AN/KSQ-1 (EPLRS); OC-120 and a UHF/VHF/FM TV antenna. The electronic controls and signal processing equipment of all of these sensors and antennas are located within the ship, not in the masts themselves.

3.9.2 Cable Runs/Electrical

In order to provide power and control signals to the antennae and send/receive signals, an assortment of cabling/waveguides will be run to each antenna. These cables/waveguides will be encased in dedicated ballistic trunks. The ballistic trunks offer some minimum level of ballistic

hardening protection and electromagnetic interference (EMI) shielding. The ballistic trunk is constructed from 1.6 cm (0.625 in.) thick High Strength (HS) steel.

3.9.3 Heating and Ventilation

Fan rooms are currently planned to be located on the level just below the forward and aft masts. Louvers in external bulkheads will provide fresh air to the fan/filter/heater units. In cold climates, where the ambient temperature drops below 40°F, the heater will maintain the temperature in the mast spaces above this lower temperature limit. In the summer when ambient temperatures exceed 105°F, cool Collective Protection System (CPS) discharge air will be used to cool the spaces within the forward and aft masts. The exhaust point for the two masts will be at the top of the masts.

Figures 5 and 8 illustrate the ventilation arrangement for the aft and forward mast AEM/S Systems respectively. The aft mast will employ an A2-1/2 fan with a heater and filter unit. Ducting will provide ventilation to the aft AEM/S System as well as the aft mast trunk to cool both the SPS-48E radar filter and the Challenge Athena filter. The forward mast will utilize an A1 fan unit with a heater and filter attached. The ventilation arrangement for the forward mast would provide air to the mast equipment test room of the 05 level as well as the forward AEM/S System intermediate radome area.

3.10 Operation/Manning

The AEM/S Systems, forward and aft, are designed as unmanned spaces under normal operating conditions. The only time personnel are expected to be aloft is to perform maintenance or repairs on the equipment.

3.11 Safety Systems and Equipment

3.11.1 Counter Measure Washdown (CMWD) System

The LPD17 AEM/S System masts will be equipped with full height counter measure washdown systems. These systems are designed to wet down the entire external surface area of the masts if the threat of a chemical weapon attack materializes. This system could also be activated in the event of an external fire threat to either of the mast structures.

3.11.2 Smoke Detection System

Both the forward and aft masts will be equipped with smoke detection systems. These systems will be similar to the Kiddie Firehold™, which was installed on the RADFORD as recommended in Reference [5]. This type of system uses air sampling technology with a master sensor. The distinguishing feature of such technology is the ability to detect small concentrations of smoke within short periods of time relative to the incipient fire/ignition. Sampling ports will be located in the overhead of protected spaces.

3.11.3 Internal Suppression Systems

An internal deluge water spray suppression system has been designed for the forward and aft masts. These systems are designed to protect each internal radome section of the masts. The systems are designed to provide in excess of 0.15 gallons per minute per square foot of surface area of composite to be wetted down. The nozzles have been chosen such that the spray patterns will cover the sensor foundations, platforms and lower one third to one half of the sidewall construction of each radome section. This water design density exceeds the concentration required to control surface flame spread which should preclude incipient fires from involving significant portions of composite material provided that the system is activated in a timely manner. Several options for activating the deluge water spray systems follow:

- manual activation capabilities from damage control central and from the access point/pressure lock should be provided at a minimum;

- the water spray system could be configured to be automatically activated upon a "high" level smoke detection event in addition to the manual activation mode; or

- the water spray system could be automatically activated upon a "high" level smoke detection vent after a one to three minute delay, which would provide time to override deluge system activation.

3.11.4 Portable Extinguishers

A portable extinguisher will be installed in each of the mast spaces. Carbon dioxide (CO_2) portable extinguishers (15 lb units) will be installed in each level of the forward and aft masts.

3.11.5 Egress Related Features and Equipment

A general announcing circuit will be incorporated into each mast. Sound powered phones are not necessary for two way communication as the LPD17 will be outfitted with HYDRA communications equipment. Emergency lighting will be provided at each level of the forward and aft masts to ensure that occupants can locate the entry/exit points in the event of a power outage. Emergency escape breathing device (EEBD) stations will also be provided at each level.

3.11.6 Lightning Protection

The forward and aft AEM/S will be protected against lighting strikes in accordance with the principles of NFPA 780 "Lighting Protection Code" [6]. Lighting terminals will be attached as needed. The existing exposed and enclosed metal hardware will be used as lighting terminals

or as conductive paths to the ship's hall. Bond straps and jumpers will be added, as needed, to complete paths for lighting currents to flow downwards.

4.0 DESIGN REVIEW

The current design for the forward and aft AEM/S System masts for the LPD17 have notable similarities and differences when compared with the ATD AEM/S System mast installed on the RADFORD. In general, the LPD17 designs reflect significant improvements over the ATD AEM/S System design. The current forward mast and aft mast designs have incorporated numerous elements from the Fire Performance Requirements detailed for the ATD mast [7].

The design, configuration, equipment and usage of the LPD17 masts are very similar to that of the ATD mast. The composite assemblies planned for use in the construction of the masts use the same glass fiber/Derakane vinylester resin matrix. The assemblies utilize a sandwich configuration with either balsa wood or polymeric foam cores. The electromagnetic sensors and antennas housed in the mast spaces do not represent significant fuel loads or ignition sources. This is similar to the ATD mast. There is also a lack of ignition sources that would precipitate a large exposure fire for the composite structures enclosing the spaces. The lack of fuel loading and ignition sources for peace time situations results in a very low risk of a fire event.

The current design also includes several safety-related features such as a high sensitivity smoke detection system, portable fire extinguishers, EEBD stations, climber safety equipment and emergency lighting. These features are in accordance with previously published recommendations relative to the ATD mast [1, 5].

The current LPD17 mast designs make several notable departures from the ATD design. The two most pronounced features are the full CMWD system which provides external wetting coverage for the outer shell of the forward and aft masts and the internal deluge water spray systems which protect all levels/radomes of the two mast structures. These systems represent

effective means of mitigating fire exposures from either exterior or interior locations. The ATD mast was not equipped with a full internal suppression system and only a partial CMWD system wetted the first 8 feet of mast structure above the 03 level. The full fire hazard analysis report [1] did recommend a full internal suppression system in order to rapidly and effectively deal with internal fire scenarios. This recommendation was made in light of the difficulty in accessing the upper spaces of the ATD mast in a short time frame for manual firefighting activities. The presence of the full height CMWD system and the complete internal deluge water spray system provide expedient and effective means for mitigating fire threats/scenarios without having to rely solely on manual intervention.

The presence of the internal suppression system was the basis to omit the hose reel, which was installed in the base of the ATD mast. The inclusion of the internal suppression system changes the philosophical approach to dealing with mast fires above the base compartment. The strategy changes from one which requires manual firefighting efforts to one where the installed suppression system can control/extinguish the fire with minimal manual firefighting efforts. As such, the 1.9 cm (0.75 in.) hose reel, which was installed in the base of the ATD mast, is not currently specified for the LPD17 masts.

The access arrangements for the LPD17 masts also depart from the ATD mast. The ATD mast design required access to the mast from the weather. Access to the LPD17 masts is internally from the ship. In order to gain entrance into the lower level of either the forward or aft mast, crew must pass through a pressure lock (hatch in the overhead served by an inclined ladder) on the level below and ascend up an inclined ladder and through a hatch in the overhead into the lower level. From the lower level of the aft mast there is a fixed ladder system with an intermediate platform to access the SPS-48E radome space. There is a three-section extension ladder in the SPS-48E space to access the crow's nest of the aft mast. The forward mast relies on foldable ladders for access of the upper intermediate space and crow's nest. The foldable ladder and the telescoping extension ladder are mounted and stored at the point of actuation/erection. This is a significant improvement over the RADFORD ATD AEM/S portable ladders, which are stored and must be manually carrier to the installation point and erected with minimal mechanical

foldable ladders for access of the upper intermediate space and crow's nest. The foldable ladder and the telescoping extension ladder are mounted and stored at the point of actuation/erection. This is a significant improvement over the RADFORD ATD AEM/S portable ladders, which are stored and must be manually carrier to the installation point and erected with minimal mechanical assistance. As previously mentioned, climber safety equipment will be provided on ladders requiring such devices.

The ventilation design for the LPD17 masts is somewhat simplified in comparison to the ATD mast. Fan rooms have been incorporated into the levels just below the mast's lower level. Each of these two fan rooms contain a fan/filter/heater unit to supply the mast with warm air in cold environments. The fan/filter/heater unit represented the most obvious ignition source/exposure fires for the ATD mast since that mast had the fan/heater unit in the lower space (access space) of the mast. Thus, the relocation of the fan/filter/heater units out of the LPD17 masts marks a notable reduction in available exposure fire scenarios. The intake for these two fan rooms is through louvers mounted low in the exterior bulkhead. During hot climate conditions, CPS exhaust air will be used to cool the mast spaces. Natural exhaust vents are provided at bulwarks of each mast top.

A very important departure from the ATD mast is the design of the LPD17 joints. The ATD mast used a bonded composite joint to mount the TAS platform to the sidewall of the AEM/S structure. This joint was of concern relative to a thermal failure precipitating a structural collapse of the TAS deck. The LPD17 AEM/S System masts will utilize mechanical fasteners to attach the antenna foundation/annular platform assemblies to the sidewalls of the mast structures. In fact, all the interfaces will use mechanical fasteners, which include: the interface between the antenna foundation and the annular platform, the interface between the annular platform and the angled flange, and the interface between the angled flange and the mast sidewall. These interfaces are depicted in Figures 11 and 13. The LPD17 joint design significantly reduces the concern for catastrophic failure/collapse of the antenna foundation/annular platform assemblies due to thermal degradation of a bonded composite joint as was the case with the ATD mast.

5.0 FIRE HAZARD ASSESSMENT

Using the ATD AEM/S as a baseline, several conclusions can be drawn from the changes in the AEM/S System masts designed for the LPD17. These conclusions are topically discussed in the following sections.

5.1 Ignition Potential

The fire ignition potential for the LPD17 masts relative to equipment has been reduced in comparison to the ATD mast. Even though the risk of ignition relative to equipment and cabling was deemed low for the ATD mast, it has been reduced by the relocation of equipment. The fan/filter/heating equipment, which serves the LPD17 masts, has been located in dedicated spaces below the masts. The ATD mast had the fan/filter/heater located in the access space (base) of the mast, which presented one of the few plausible fire ignition scenarios.

The redesign of the forward AEM/S System such that the SPQ-9B rotational surface search radar is not enclosed by the composite mast but rather is served by its own radome reduces the ignition source potential for the forward AEM/S System. The remaining sensors/antennas in the forward LPD17 mast are static and do not have motorized movement.

The remaining sensors and cabling are very similar to what has been installed in the ATD mast. This maintains the limited risk of ignition for the balance of the forward and aft masts' outfitting. Furthermore, the ignition potential for the LPD17 masts, when manned, are identical to those of the ATD mast since the likelihood of fire ignition would be a function of personnel disregarding SOP (e.g., performing hot work, smoking, unauthorized storage).

5.2 Fire Development{tc \l2 "5.2 Fire Development}

5.2.1 Composite Assemblies{tc \l3 "5.2.1 Composite Assemblies}

The composite assemblies used in the LPD17 design are nearly identical to those used in the ATD mast. The size of the compartments are comparable. If a sizable exposure fire can be developed and sustained, some fire spread would be expected on the composite surfaces in the absence of mitigating activities (fire suppression systems or manual firefighting). Such unmitigated fire scenarios will result in the potential to develop environments hazardous to occupants in a relatively short time period as reflected in the ATD mast report [1].

The most recent version of the flame spread model, revised and updated since the ATD AEM/S analysis, may estimate a greater extent of flame spread for given exposure fires in comparison with the ATD AEM/S estimations. This is due to the refinements in the model and the inclusion of additional conservatism [2]. There is no full scale flame spread fire test data for the sandwich composite assemblies, which will be used in the construction of the LPD17 masts. The lack of these data would obligate the use of conservative estimations currently in the model. Although current estimations of the flame spread potential may indicate more extensive flame spread over the surface of the composite assemblies, this does not alter the recommendations, which were made for the ATD mast. The inclusion of the deluge water spray system mitigates the flame spread hazard.

5.2.2 Internal Fire Spread{tc \l3 "5.2.2 Internal Fire Spread}

The ability to access the mast spaces on the LPD17 directly from the interior of the ship may make it marginally easier to store materials in the lower compartment of the forward or aft masts. The nature of these spaces and the performance requirements of the sensors should discourage this type of activity. Because the mast outfitting and appointments offer very minimal

fuel packages for developing fires, strict adherence to prohibiting storage of any items of combustible nature is critical to avoid increasing the fire hazard of these mast structures.

The access arrangements for the LPD17 masts is via individual pressure locks. The inclined ladder, which leads to a hatch in the overhead, is isolated from the remainder of the ship by doors that lead into the enclosed companionway. Although remote, there is the potential that a fire inside the ship could spread into the masts. The ATD mast has access from the weather deck only. This design change slightly increases the risk of fire spread; however, this is mitigated by the operational characteristics of the ship, which would call for the hatch to be normally closed.

5.3 Structural

There were notable concerns associated with the bonded composite joints, which were used to attach the TAS antenna deck/platform to the side walls of the ATD mast. The concern focused on the potential failure of this joint under elevated temperatures associated with a fire in the SPS space. The joints, which attach the antenna foundations/annular platforms to the side walls of the LPD17 masts, have been redesigned. The extensive use of mechanical fasteners has significantly reduced the concerns associated with this aspect of the structural design of the LPD17 masts.

5.4 Access/Egress of Mast Spaces

The use of either a) fixed ladders, b) telescoping extension ladders or c) foldable ladders rather than portable ladders which must be "installed" improves access to the upper levels of the LPD17 masts. The foldable and extension ladders are stored at the point of actuation and have mechanical assistance to erect the ladders in a more expedient fashion. This type of configuration improves the ability to erect the ladders in high sea states as well.

5.5 Fire Fighting

5.5.1 Fixed Systems

The design decision to include full CMWD coverage for all external portions of the LPD17 masts improves over the ATD mast partial CMWD. The full coverage CMWD provides a mitigation mechanism in the event that there is an external fire threat to either the forward or aft masts. Exterior protection can be augmented with hose streams.

The inclusion of deluge water spray systems for both the forward and aft LPD17 masts is the most significant design change in comparison with the ATD mast. This protects the forward and aft mast spaces with a remotely operated suppression system. The effectiveness of the deluge system is increased as it is augmented with the high sensitivity smoke detection systems in either an interlocked or non-interlocked configuration. This provides a high degree of protection when combined with the fire hazard and fire risk associated with the LPD17 AEM/S System masts for peacetime fire scenarios. The fire risk is very low for the spaces comprising the LPD17 masts because ignition sources are minimal and there are only minor fuel packages.

5.5.2 Manual Firefighting Considerations

The access arrangements through the interior of the ship may make manual firefighting access and response slower than weather access to the ATD mast. A direct comparison on this issue is difficult due to the number of variables such as sea state, weather and equipment location relative to mast access. The impact to firefighting doctrine is detailed in Section 6.0.

6.0 PREVENTION AND MITIGATION STRATEGIES

6.1 Fire Prevention

Recognizing that the risk and hazard of fire can never be completely eliminated, a fundamental strategy to minimize any existing risk is to prevent fire incidents from occurring. The fire prevention strategy developed for the ATD AEM/S System mast is also applicable to the LPD17 masts. The goal of the fire prevention strategy is to:

- limit or reduce potential ignition sources; and
- limit or reduce the presence of residual combustibles/fuel sources.

Design features and administrative requirements have been developed which should reduce the likelihood of a fire incident.

Smoking: Although fuel sources within the LPD17 AEM/S System masts should be very low, smoking in the structure should be prohibited. Warning placards, which indicate this prohibition, should be displayed at the entrance point to each of the mast structures.

Welding/Hot Work: Historically, welding and hot work have been a significant cause of Navy shipboard fires [8-11]. Since the majority of the mast is combustible composite, two conclusions can be drawn:

- the composite assemblies provide a readily available fuel source; and
- the need for welding/hot work should be minimal due to the lack of candidate materials, which would require hot work.

All hot work and welding in the mast should be prohibited. Warning placards should be displayed at the entrance point to each of the mast structures. In the event that upgrading sensor suites requires hot work to remove radome sections via the detachable joists, the shipyard should adopt a hot work permit/fire watch plan.

Storage in the Mast: The LPD17 forward and aft masts are normally unmanned spaces and will have restricted access. As such, unauthorized use of the space should not be a significant problem. Currently, there are no plans to use the space within the mast for storage. Even for the smallest fires of concern, additional fuel load beyond what is readily apparent is required to create potential fires large enough to involve a significant surface area of composite material. Additional fuel load could occur as a result of unauthorized storage in the mast. Therefore, there should be absolutely no storage of anything within the mast or adjacent to the mast base. Warning placards should be posted to this effect.

Maintenance: The need for maintenance should be minimal; however, in the event it is necessary, only solvents which are noncombustible (i.e., no flashpoint) should be used. If no such solvent is available, quantities used should be minimized.

Lightning Protection: As detailed in Section 3.11.6, the threat of ignition from a lightning strike can be addressed with the installation of lightning protection systems which meets the intent of NFPA 780 [6]. This strategy should provide protection for the mast and minimize or eliminate the potential for ignition and fires resulting from lightning.

6.2 Egress and Life Safety

The AEM/S System represents an enclosed environment; therefore, life safety of any occupants within the mast and egress from the mast are important concerns. Since the mast is normally unmanned, life safety and egress are only factors at those times when personnel are working in the structure. Those times should be limited to the mast installation and periods of

The AEM/S System represents an enclosed environment; therefore, life safety of any occupants within the mast and egress from the mast are important concerns. Since the mast is normally unmanned, life safety and egress are only factors at those times when personnel are working in the structure. Those times should be limited to the mast installation and periods of maintenance. Egress and life safety issues cover the concerns for occupant safety during emergency exiting as well as during the routine presence of personnel. Several design features, which address egress and life safety, have been incorporated into the design of the LPD17 masts. It is recognized that personnel working in this space will follow standard "Man Aloft" procedures, which should further enhance personnel safety.

The following design features and design recommendations improve the overall level of life safety for occupants in the mast. These features will be augmented with other design features, such as a means for early fire detection, portable extinguishers and a deluge water spray system. This strategy not only provides additional time for egress or crew to respond to the event, but allows for a response, which may avert life threatening conditions from developing.

<u>Exits</u>: Occupants of the upper mast levels have only one exit path: down via the ladders they used to ascend. In general, a minimum of two exit paths should be provided from occupancies in order to avoid trapping persons in an emergency. However, the LPD17 masts are normally unoccupied spaces and secondary alternative exit paths for the LPD17 AEM/S forward and aft masts are not feasible. The fire modeling performed for the ATD mast indicated that relatively small fires could generate conditions, which would prevent crew from descending down and out of the mast. There is nothing, which would indicate that the LPD17 masts are different in this respect. The deluge water spray system should be capable of preventing a fire from generating and sustaining untenable conditions for unprotected personnel. In the event that occupants feel that untenable conditions were developing and preventing them from descending the mast they can wait in the crow's nest area. This approach recognizes the crow's nest area of each mast as an area of refuge in the unlikely event that occupants cannot descend the ladders. Mast-specific doctrine should reflect the use of the bulwark areas as areas of refuge.

Ladders: Ladders provide the only means for egress from above. The ladders will be constructed of aluminum or steel. The current design calls for folding aluminum ladders. Long spans, such as the SPS-48E space, should be equipped with climber safety equipment. This is also part of the current design.

Access Points: Access through closures should not inhibit or degrade egress capabilities. If closures are planned for the hatchways or scuttle openings, they should not require significant effort to operate. This will be especially significant for firefighters who may be encumbered when attempting to operate these closures. Heavy or awkward closures should be fitted with quick-acting mechanisms.

Communication: The ability to communicate between levels within the mast and with other areas on the ship is important. This provides at least one mechanism for passing critical information to those at risk. The ATD mast required sound powered phones at each level; however, the LPD17 will be equipped with HYDRA (hand-held portable communicators) which provides the same ability without requiring personnel to be at a single location (sound powered phone station). A general announcing 1-MC circuit should be installed at each level of the mast.

Emergency Breathing Devices: The potential exists for fire, which would generate smoke-filled conditions in spaces of the LPD17 mast. Occupants on the upper levels may face the possibility of descending through smoke-filled spaces to egress either of the masts. These factors support the recommendation for providing emergency breathing devices to facilitate quick and effective egress from the structures. EEBD stations should be located at each level of the forward and aft LPD17 masts. In the absence of this, belt mounted SEEDs could be required for personnel entering the masts.

6.3 Detection

Because the AEM/S System masts are normally unmanned areas and employ combustible construction, there is a potential for significant fire growth before discovery. Although the

likelihood of such an event occurring is low, the potential for unmitigated fire growth for an extended time frame will be countered with the installation of an automatic smoke/fire detection system. This mitigates the lack of a second exit (i.e., provide early warning for rapid egress) and potentially reduces the effort required for manual firefighting (i.e., fire would be fought in the incipient stages). The deluge water spray system capabilities in conjunction with the early detection capabilities should control/extinguish any peacetime fire threat prior to untenable conditions developing in the spaces of either LPD17 mast.

An evaluation of smoke/fire detection systems in the context of the AEM/S System ATD was performed [5]. The conclusion of this effort was that a detection system possessing high sensitivity and quick response should be used in the prototype AEM/S System ATD mast. Due to the limitations imposed by the AEM/S System ATD design and the concern for Electro-Magnetic Interference (EMI) and Radio Frequency Interference (RFI), the available choices for detection system technologies was limited. VESDA, a remotely located smoke detection system, which employs gas sampling technology, was recommended [5]. Other remotely located gas sampling detection systems are available and are acceptable provided that the sensitivity performance is comparable to the VESDA systems.

6.4 Fire Suppression

Although there is a relatively low probability of ignition, a fire could occur which involves the composite structure and/or electrical equipment in the masts. An exterior exposure fire could also involve either of the exterior mast structures. Provisions should be made to combat a fire involving the LPD17 masts. This could include portable firefighting equipment or installed, fixed systems. The fixed systems could support manual firefighting. Firefighting capability should address incipient fires and fires that are growing or well-developed.

6.4.1 Portable Equipment

Because any manual firefighting of a growing or well-developed fire would likely involve personnel operating on the ladder, it is highly desirable to extinguish fires in the incipient stage. When personnel are working in the space (e.g., required maintenance), portable extinguishers should be available. If the space is unmanned, intervention of an incipient fire can be accomplished with portables if the fire is discovered by personnel or detected by an automatic detection system (see Section 6.3). It is likely that a fire precipitated by the presence of personnel in either of the LPD17 masts will be detected by the same personnel. In this case, it is hoped that the personnel on hand would extinguish the fire with the portable extinguishers available. An incipient fire may also be detected by the failure of radar or antenna equipment located in either of the masts.

Portable fire extinguishers should be provided to control Class C (e.g., radar equipment) fires as the only readily available ignition sources are electrical in nature. They should be located so that personnel do not have to climb the access ladder with an extinguisher. Existing Navy equipment could be used. Portable 6.8 kg (15 lb) carbon dioxide extinguishers (MIL-E-24269) should be used for Class C fires. The current design has targeted the installation of a carbon dioxide extinguisher at each level of both the forward and afts LPD17 masts.

6.4.2 Fixed Systems

To address growing or well-developed fires, fire suppression equipment with capabilities beyond portable extinguishers should be provided. This could take the form of hand hoselines/standpipe systems and/or fixed suppression systems.

Fire threats to the external structure of either the forward or aft LPD17 AEM/S System masts can be initially mitigated with the use of the full CMWD system, which will be installed on both structures. As discussed in Section 3.11.1, the CMWD system is designed to wet the entire external surface area of the masts. This capability can be augmented with hose streams, if

necessary. Although the potential for a peacetime external fire exposure threat is unlikely, the CMWD system should prove beneficial in mitigating such an exposure. The CMWD offers the greatest benefit in mitigation of battle induced threats to the LPD17 masts. This should be reflected in the ship doctrine.

The AEM/S System ATD mast utilized a 1.9 cm (0.75 in.) hose reel. The hose reel provided a "quick response" capability for manual intervention in the event of a fire incident. The previous ATD fire hazard analysis recommended a fixed water spray system. The LPD17 AEM/S System masts have embraced this recommendation and included fixed, deluge water spray systems throughout each space of the forward and aft masts. This system, which can be activated manually, or through the smoke detection system interlock will provide the capability to control/extinguish fires in the early stages. Because the air sampling smoke detection system offers high sensitivity and rapid detection capabilities, the deluge water spray system should be activated quick enough to extinguish mast fires regardless of the activation methodology. This greatly reduces the need for manual fire fighting capabilities. It does not entirely eliminate it, as firefighters will be required to investigate and clean up residual combustion hot spots.

6.5 Passive Fire Protection

Passive fire protection strategies typically focus on preventing either fire spread between adjacent compartments or structural failure of key components. The LPD17 masts have been designed to be relatively isolated from the remainder of the ship. Each mast has cable/ballistic trunk penetrations, a ventilation duct penetration, and a hatch connection (to the pressure lock access).

6.5.1 Cable/Ballistic Trunk Deck Penetrations

Penetrations of the interface deck (04 Platform level deck for the aft mast and the overhead of the 05 Platform level for the forward mast) by cables or ballistic trunks should be protected. Protection of these deck penetrations is important to limit the vertical flame spread potential associated with wires and cables. These penetrations should be protected by approved fire stops, which would prevent a fire from within the ship from spreading into a mast. Multiple Cable Transits (MCTs), which have been fire tested, provide the best penetrations protection.

6.5.2 Ventilation Penetrations

The ventilation connections to the mast will utilize non-combustible duct work. This should adequately protect the penetration and prevent flame passage provided that the penetration is fire stopped.

6.5.3 Hatch Openings

The means of access into both LPD17 masts relies on an inclined ladder in a pressure lock which leads to an overhead hatch. The pressure locks provide an inherent safeguard against fire spread into the masts. Since the pressure lock doors and associated hatches are normally closed, this precludes fire spread through these access points.

6.6 Damage Control and Firefighting Doctrine and Tactics

In general terms, the mast represents a Class C ignition risk which is enclosed in a combustible structure. Composites can be readily ignited when exposed to medium to large sustained exposure fires. Current outfitting plans preclude either space contents or functions from resulting in medium to large exposure fires. Once ignited, the involved composite can generate smoke in quantities large enough to impair tenability. Burning characteristics are such that flames

should not, under most conditions, spread rapidly when exposed to localized ignition sources. Fire can be readily extinguished with water or water-based extinguishing agents. Fires involving electrical equipment should be fought with CO_2 extinguishers.

Standard firefighting doctrine and tactics, where applicable, should be followed as specified in NSTM 555 [12] and NWP 3-20.31 [1]. The LPD17 AEM/S Systems present unique fire challenges for the shipboard firefighter. For in-port scenarios, the in-port fire party should respond. For at-sea scenarios, the at-sea fire party or appropriate repair party should respond.

Although the probability of a major fire is low, the nature of potential fuel sources and the complications presented by a vertical attack to the seat of the fire warrant special considerations to ensure a safe and effective fire attack. Additional firefighting doctrine is provided below to assist the shipboard firefighter in implementing a fire attack plan which will provide a rapid and continuous response to an AEM fire incident.

6.6.1 Mast Specific Firefighting Doctrine

Initial Action for Fire Internal to AEM/S System Masts: The initial actions by a person who discovers a fire within the AEM can make the difference between a controllable fire and one which threatens to cascade into a major fire incident. The predominate fire threat for the composite mast structure encompasses a Class C fire and possible ignition of Class A fuels. Every effort should be made to secure and isolate those systems and equipment that are the root cause of the fire. Complete electrical isolation may be difficult, and command mission priorities may preclude immediate system isolation if they are essential to the safety or fighting capability of the ship. It is imperative that a preplanned isolation strategy be developed to ensure all controlling actions are expeditiously administered. The basic attack philosophy should be a direct attack on the seat of the fire utilizing a two-man quick attack team. The Number One responder serving as the primary investigator should quickly ascend the mast structure and advance to the immediate fire area. Once the seat of the fire has been determined, the Number one responder should control/extinguish the fire with portable extinguishers which are pre-staged at each level of the

forward and aft LPD17 masts. The Number Two responder should serve as a back up to the Number One responder. The Number One responder should communicate with the Number Two responder in terms of assessing the situation: the fire can be controlled with portable equipment; the fire is small but requires additional agent (extinguishers or hose line); the fire is growing and the manual deluge water spray system should be activated. The Number Two responder should react according to this assessment:

1) Bring additional extinguishers to the Number One Responder.

2) Start to stage a hose line.

3) Wait for the Number One Responder to safely exit down the ladder, and request approval of the DCA/Commanding Officer to activate the installed suppression system. Based on this approval, activate the internal deluge system.

Under any of these conditions, the Second Responder should be advising the DCA of the need for more equipment/manpower. The ship should consider the pre-staging of 1.5 in. (3.8 cm) handlines near the mast access for use in the event of a fire.

Personnel protection equipment should be limited to breathing protection (OBA or SCBA) and radiant heat protection (gloves/flash hood). An additional 3.8 cm (1.5 in.) hoseline should be staged outside the mast structure to ensure a continuous response in the event the fire escalates in intensity and/or the mast is abandoned by the initial attack team.

<u>Desmoking</u>: Positive pressure ventilation (PPV) may help maintain visibility and reduce the build-up of heat or flammable gases within the mast structure. The use of portable "box" fans should be used to augment the make-up air supply. The installed supply ventilation system should be shutdown during fire attack. Local emergency control over the ventilation system at each individual mast should be provided near the access points.

Initial Actions for Fire External to AEM/S System Masts: In the event of a superstructure fire, all controlling actions should be directed to cooling the external surfaces of the mast structure which is closest to the external heat source. The CMWD system should be activated immediately. Two 3.8 cm (1.5 in.) hoselines should be staged and cooling water applied as necessary. If possible, the OOD should position the ship to minimize direct flame impingement to the mast structure.

Training: In the unlikely event that handlines are needed in the upper levels of the masts, firefighters should be prepared with proper techniques. Training evolutions should be performed in both masts to determine the best approach and preferred equipment for manual firefighting in the masts. A fire plug with enough pre-staged hose to ascend to the top of the mast should be located close to the access point of each mast.

7.0 SUMMARY AND RECOMMENDATIONS

The LPD17 AEM/S Systems design represent a significant improvement over the RADFORD ATD AEM/S Systems relative to fire risk and fire hazard. With the relocation of the fan/filter/heater units below the mast and mounting the SPQ-9B radome on top of the forward AEM/S System, plausible ignition sources as well as potential exposure fire scenarios have been reduced. Access/egress has been improved with the use of fixed, extension or foldable ladders as opposed to portable ladders. Full CMWD system coverage for the AEM/S System externals and the inclusion of deluge water spray protection for all internal spaces is an important improvement for active fire suppression protection for those structures.

The risk of a fire incident for the LPD17 masts has been considerably reduced in comparison to the ATD AEM/S Systems which was previously characterized as very low. The fire hazard (characterization of the likely impact of a fire event) for the LPD17 masts is similar to that of the ATD mast which was determined to be low. The life safety of occupants has been improved with the omission of portable ladders as well as the redesign of the joint system between the antenna foundations and the side walls of the masts. The improvements in active/automatic

suppression capabilities integrated with the design of the LPD17 masts are pivotal in managing the fire hazard associated with either internal or external fire scenarios. The effectiveness of the internal deluge water spray systems is notably increased when coupled with the early detection capabilities of an air sampling smoke detection system. Overall, the design of the LPD17 AEM/S Systems adequately manages the fire risk and fire hazard associated with the combustible composite materials. The fire protection features which can be used to address the threat include fire prevention, life safety and egress, detection, suppression and passive features. Each of these aspects has been expanded below. Based on this list of either current design features or recommended fire protection features, appropriate firefighting doctrine and tactics using a quick response philosophy can be implemented.

1. Fire Prevention – Ignition sources inherent in the design of the LPD17 masts are negligible. The creation of a large area of fire involvement would most likely occur as a result of an external fuel spill (e.g., unexpended weapons or aircraft incident) or accidental/intentional ignition of unauthorized combustibles which may be stored inside the mast. Design features and administrative requirements should be used to reduce the likelihood of ignition:

    a. A fixed lightning protection system has been designed for installation on both the forward and aft LPD17 masts.

    b. Combustibles should **NOT** be stored inside either mast or adjacent to either mast structure. Warning placards which indicate this prohibition should be displayed on both mast structures.

    c. Ignition sources in and around the mast structures should be minimized:

(1) Smoking in the structures should be prohibited. Warning placards which indicate this prohibition should be displayed on the mast structures.

(2) Welding and hot work in the masts should be prohibited. However, undesirable, mission critical hot work could be performed provided adequate fire watch procedures are followed.

d. Sensor lubricants and solvents used for routine maintenance should be noncombustible (i.e., no flashpoint).

2. Egress and Life Safety – Since the mast is normally unoccupied, life safety and egress are only factors when personnel are working on the structure (e.g., construction and maintenance). There is only one effective exit from the upper levels of each mast, via the ladders. Alternative secondary exit paths are not considered feasible. An approach should be adopted which recognizes the crow's nest areas as areas of refuge in the unlikely event that personnel cannot descend the ladders. Egress and life safety features should be combined with other features (e.g., early detection) to provide a reasonable level of life safety.

a. Adequate visibility should be provided in the event of a power failure. Emergency lighting at all levels (with emphasis on ladders and access openings) should be installed.

b. Access through closures should not inhibit egress. Closures, if installed, should not require any significant effort to operate (e.g., quick-acting mechanisms for any closures, or light weight hatches).

c. Communication capability should be provided for each deck of the mast. A single general announcement circuit should be provided within the mast. Effectiveness of HYDRA communications should be assured within these masts.

d. Emergency breathing devices should be provided for quick escape. EEBD stations should be located each level of the forward and aft masts.

3. Detection – To enhance the rapid detection of a fire in unmanned spaces, the installation of a fixed fire detection system will be provided. Reference [7] provides a review of the design factors. A smoke sensing system of the air sampling type is the best option to provide the required sensitivity (for the rapid-response concept) and EMI hardening.

4. Suppression – Manned firefighting operations in the mast will be difficult if a fire is well advanced (consequently, the early warning detection recommendation). Manual fire suppression capability should be provided to control incipient fires, to provide for quick response and attack, and for follow-up firefighting of an advanced/well-developed fire:

a. Install fixed suppression systems:

(1) External CMWD system will be extended to provide complete external coverage for each mast.

(2) Internal deluge water spray system which protects each level of the LPD17 masts will be installed. Manual activation provides adequate performance given air sampling smoke detection systems. If even faster response is desired, the water spray system could be interlocked with

the smoke detection system (with or without an override delay).

b. Portable fire extinguishers should be provided in the mast space for attack/control of incipient fires. A portable CO_2 extinguisher should be provided in each enclosed level of both the forward and aft LPD17 AEM/S Systems.

c. A fire plug should be available in the immediate vicinity of each mast entrance.

5. Passive Fire Protection

a. There should be provisions to limit vertical flame spread along ballistic trunks/cable runs. Any penetrations between the lower level of the forward and aft masts and the remainder of the ship should be limited to prevent fire spread. Cable way/ballistic trunk penetrations should be protected with approved fire stops. This addresses fire spread outside the ballistic trunk, at the deck penetration.

b. Ventilation penetrations should provide basic fire stopping to prevent flame pass through. Ventilation duct work should be steel.

6. Firefighting Doctrine – Ship specific firefighting doctrine should be developed and adopted based on information contained in this report (See Section 6.6.1). This doctrine should emphasize the "quick response and attack" philosophy. Use of portables to attack incipient fires should be emphasized.

a. Local emergency control over the mast ventilation system should be provided. An emergency ventilation control switch near the access to the mast should be provided as a means to secure the ventilation.

b. There is some question as to the ability of firefighters to handle a 3.8 cm (1.5 in.) handline on the ladder. Training evolutions should be performed on a mast ladder to determine the preferred equipment and technique for manual firefighting above the access space.

c. If portable extinguishers are not adequate to extinguish fire then the deluge water spray system should be activated or if the smoke detection system indicates a fire the deluge water spray system should be activated.

d. Although the deluge water spray system can be interlocked with the smoke detection system, manual activation of the water spray system is recommended. The early detection capabilities should provide enough time to investigate the smoke alarm. If this investigator finds a fire that cannot be controlled/extinguished with portable extinguishers, the deluge water spray system can be activated.

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